NONINVASIVE SENSOR SYSTEM TO ASSESS TISSUE PERFUSION AND GUIDE RESUSCITATION

Babs R. Soller, PhD

University of Massachusetts Medical School

BACKGROUND: Hemorrhage is a major cause of soldier death, particularly in the first hour of injury. To help soldiers survive major injury, seriously injured soldiers must be quickly identified and appropriate resuscitation techniques applied. Currently there is no way to assess severity of injury and therefore direct resources in a manner that will save the largest number of lives. Quick response to hemorrhage is key to survival, as is applying timely and appropriate resuscitation techniques. In Iraq today, a soldier's care must sometimes be delayed until they are transported to a hospital far from the battlefield, requiring constant monitoring to provide an early warning of delayed shock resulting from the initial casualty. Significant loss of blood leads to inadequate organ perfusion and tissue oxygenation. The goal of resuscitation from shock is to correct the mismatch between available oxygen and the demands of critical organs. Quick response to hemorrhage, within the first hour, can prevent cardiovascular collapse and death. However, under-resuscitation from shock may lead to serious complications and delayed mortality. Traditional systemic markers of shock have been found to be inadequate markers of successful resuscitation. We have developed a system to explore the regional measurement of muscle pH and oxygen to assess tissue perfusion and to assist in providing effective resuscitation from shock.

PURPOSE: Develop an easy to use, noninvasive system which measures muscle oxygen, muscle pH and blood hematocrit. Demonstrate the system on human subjects experiencing reduced muscle perfusion.

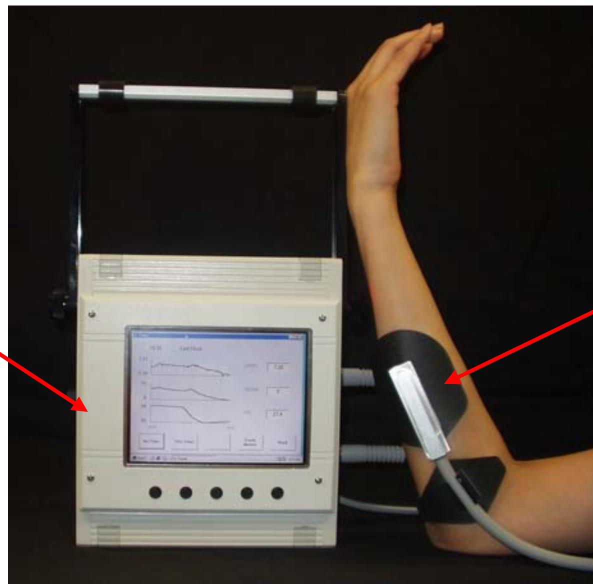
METHODS: We designed a sensor system based on near infrared spectroscopy to measure deep muscle pH and oxygen noninvasively. The system is comprised of a fiber optic sensor which sits on the surface of the forearm. White light from the attached monitor is delivered through skin and fat deep within the muscle. Light reflected from the muscle is converted to an absorbance spectrum. The absorbance spectrum is processed by three mathematical algorithms developed by our team to report absolute values for the 3 parameters. Values can be displayed continuously over time to determine effectiveness of treatment. Spectroscopic measurements were compared to venous blood values during handgrip exercise to simulate increased muscle oxygen demand. In a pilot study, the system was evaluated on 3 subjects experiencing lower body negative pressure (LBNP) as a laboratory model for progressive hemorrhagic shock.

RESULTS: The system design was based on the military's need to provide rapid response and eventual use by combat medics. The system has a novel lamp circuit to eliminate warm-up time of the light source. Innovative design of the sensor head eliminates stabilization time required by sensor-induced variation in skin blood flow. The sensor head also incorporates a dual-source design with novel mathematical processing to remove the spectral influence of skin color and fat, providing assessment of oxygen and pH in the muscle alone. User software automates the measurement. Data collection is started by a single button press. The system then optimizes spectral output for each individual subject. The system was evaluated on human subjects during rhythmic handgrip exercise at 3 intensities, and subsequent hyperemia following exercise. The sensor measurements were found to be correlated with oxygen saturation and pH in venous blood drawn from the exercising muscle. In the pilot LBNP study the system showed promise for early detection of hemorrhagic shock and was found to be responsive to compensatory physiology observed in these normal subjects. Ten systems were constructed; two will be delivered to the US Army Institute of Surgical Research in January, 2006 to continue the LBNP work and to study blood loss during surgery on burn patients.

CONCLUSION: A novel sensor based on near infrared spectroscopy and innovative mathematical methods was developed to noninvasively assess the severity of hemorrhage and help guide resuscitation. Preliminary system evaluation was completed on human subjects and the systems are being delivered to the US Army for further evaluation.

PRODUCT/TECHNOLOGY DESCRIPTION: We have designed and built a sensor system based on near infrared spectroscopy to measure deep muscle pH, oxygen and blood hematocrit noninvasively. The system is comprised of a fiber optic sensor which sits on the surface of the forearm. White light from the attached monitor is delivered through skin and fat deep within the muscle. Light reflected from the muscle is converted to an absorbance spectrum. The absorbance spectrum is processed by three mathematical algorithms developed by our team to report absolute values for the 3 parameters. Values can be displayed continuously over time to determine effectiveness of treatment. A photo of the instrument is shown below. The monitor is 8" x 9" x 5" and weighs approximately 8 lbs. During a technology demonstration we can make static measurements on meeting participants or demonstrate real-time changes in the measured parameters during rhythmic handgrip exercise.

Optoelectronic monitor with light source, spectrometer , and on-board computer which collects spectra, calculates measure-ment parameters and displays results continuously in real-time.



Fiber-optic sensor in metal housing, held in place with shield to eliminate ambient light.